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ORIGINAL PAPER

Floristic and structural analysis of the woodland vegetation around Dello Menna, Southeast Ethiopia

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Abstract: Floristic composition and vegetation structure were described for the woodland vegetation around Dello Menna, Bale zone, southeast Ethiopia. A total 50 (20 m × 20 m) quadrats were sampled to identify and describe plant community types, species diversity, richness and evenness and to relate the identified plant community types with some environmental factors and describe the population structure of woody plant species. In each quadrat, data on species identity, abundance, height and Diameter at Breast Height (DBH) of woody plant species, altitude and slope were recorded. Vegetation classification was performed using PC - ORD software package. Sorensen's similarity coefficient was used to detect dissimilarities among communities. Shannon - Wiener diversity index, species richness and Shannon's evenness were computed to describe species diversity of the plant community types. Results show that a total of 171 vascular plant species representing 53 families were recorded. Fabaceae is the dominant family represented by 13 genera and 26 species (15%) followed by Asteraceae, Lamiaceae and Anacardiaceae with eight species each (4.6%). Based on the results of vegetation classification, three plant communities (*Dalbergia microphylla* community, *Grewia bicolar*- *Acacia brevispica* community, and *Combretum molle*-*Combretum collinum* community) are recognized and described. Species richness, diversity and evenness varied among the plant communities. Species richness and diversity exhibit a bell - shaped pattern along altitude. Species turn over among communities more or less follow altitudinal gradients. Tukey's pairwise comparison of means among the plant community types shows significant variations in altitude, implying that altitude is one of the most important factors determining the distribution of plant communities. The community *Dalbergia microphylla* type exhibits the highest species richness and diversity. Analysis of population structure of the dominant species reveals various patterns. Future research directions and recommendations are suggested for the sustainable utilization of the vegetation.

Keywords: altitude; plant community; species diversity; species richness; vegetation structure

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Introduction

Ethiopia hosts the fifth largest floral diversity in tropical Africa (EWNHS 1996). This results from the wide variations in climate, geology and terrain working on different time scales (EWNHS 1996; Sebsebe et al. 2003). It has very diverse climatic conditions varying from hot and dry desert in the lowland areas to cold and humid alpine habitats in the highlands. Furthermore, the vegetation is extremely complex due to great variations in altitude implying equally great spatial differences in moisture regimes as well as temperatures within very short horizontal distances (Zerihun 1999). Unfortunately, biodiversity resources along with their habitats are fast disappearing in the country as a result of human-induced factors (Demel 1992; Tadesse and Demel 2001; Tadesse et al. 2002; Tadesse 2003; Feyera 2006; Feyera and Denich 2006). If this trend of resource devastation continues unabated, there is a great danger of serious decline or loss of the biodiversity resources. On the other hand, there is a significant lack of information on the ecology and diversity of some of the vegetation types in the country. Generation of scientific knowledge could be one of the intervention mechanisms to counteract the problem and contribute to the conservation of vegetation resources and the associated biodiversity.

Plant communities are defined as recognizable units of vegetation in a uniform environment with a relatively uniform floristic

composition and vegetation structure that is distinct from the surrounding vegetation (Mueller-Dombois & Ellenberg 1974; Kent and Coker 1992). Recognition of plant communities helps in recommending appropriate management regimes for the community types as separate units deserve separate management regimes. This further helps in planning and implementing conservation strategies and sustainable utilization of plant resources. Plant communities show spatial and temporal heterogeneity across landscapes. Environmental gradient analysis provides the underlying causes for the pattern and distribution of plant communities on landscapes. Thus, the evaluation of the spatial variation of environmental variables is essential to understand the factors governing the distribution and abundance of species (Getachew et al. 2008). Besides, examination of patterns of population structures could provide valuable information about their regeneration and recruitment status that could be further employed for devising conservation and management strategies (Demel 2005). Several ecological studies have been made in Ethiopia with emphasis on plant community analysis (Lisanework and Mesfin 1989; Zerihun et al. 1989; Tamrat 1994; Minassie and Masresha 1996; Tesfaye et al. 2001; Kumelachew and Tamrat 2002; Tadesse 2003; Teshome et al. 2004; Gemedo 2004; Desalegn and Zerihun 2005; Abate et al. 2006; Feyera 2006; Simon and Zerihun 2006; Kitessa et al. 2007; Getachew et al. 2008; Haile et al. 2008), that have demonstrated the variation in several attributes of plant communities with variation in environmental variables. Despite these, studies on the ecology and flora of the woodland vegetation around Dello Menna are lacking. The present study is, thus, conducted with the following objectives: (a) to define plant community types of the vegetation, (b) to compare species richness and diversity among different plant communities, (c) to assess patterns of plant species composition along altitudinal gradient, and (d) to describe the population structure of woody plant species.

Materials and methods

Description of the study site

The present study was conducted in Dello Menna district, Bale zone of Oromia regional state, southeast Ethiopia. Dello Menna is located at 555 km south of Addis Ababa - the capital of Ethiopia, in the Bale zone of Oromia state, and 125 km from Robe town, the capital of Bale zone. It lies between latitudes 5°53' N and 6°27' N, and longitudes 39°15' E and 40°38' E. The altitude ranges from 800 to 2 000 m.a.s.l. The woodland vegetation where the study was conducted lies along the road from Menna to Bidre, the capitals of Dello Menna and Mada Walabu districts, respectively.

Dello Menna district falls within the south-eastern bimodal rain fall regions of Ethiopia (Daniel 1977). Thus, it is characterized by bimodal rainfall with the main rainy season occurring early March through June and the short rain late September through November. There are five dry months in the area, i.e., January, February, July, August and December (Fig. 1). The mean annual rainfall is 986.2 mm and the mean annual temperature is 22.3°C. The study area is dominantly characterized by plain topography with few areas of rugged and mountainous terrain. The study plots are more or less confined to the flat terrain. Nitosol is the dominant soil type in the area (Ermias et al. 2008). It is reddish brown clay towards the higher altitudes and tends to red-orange sandy soil towards the lower altitudes. Rock outcrops are prevalent along streams and sloppy hills. The inhabitants of the area are primarily Oromos. The dominant agricultural system in Dello Menna district is mixed farming with livestock and subsistence agriculture forming the major livelihoods of the rural community (Feyera 2006). Coffee, banana, and papaya are the dominant perennial cash crops. Teff, sorghum, and maize are the major annual crops cultivated by farmers.

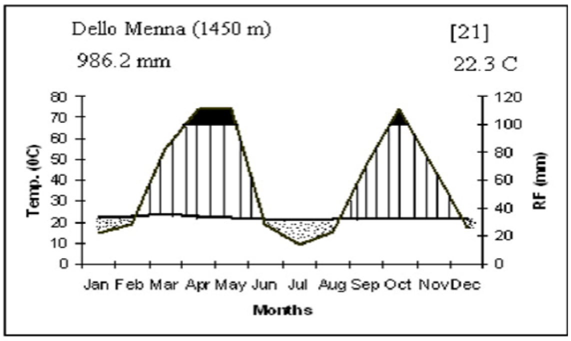

Fig. 1 Climatic diagram of Dello Menna district based on 21 years data (1986-2006) (Source: Ethiopian Meteorological Service Agency). 986.2 mm stands for mean annual rain fall; 22.3°C mean annual temperature; and [21] indicates the number of years on which the meteorological data was based according Walter's approach of climatic diagram.

Floristic and structural data collection

A reconnaissance survey of the vegetation was made from October 21–24, 2006 in order to obtain an impression of the vegetation and topographic features. Actual field data were collected from November 16 to December 8, 2006. Vegetation and environmental data were collected in sample quadrats placed in transect lines, which are systematically laid. A total of 50 quadrats were laid along transect lines. Twelve transects of four quadrats each were systematically laid across the slope. Two plots covering both sides of Melka Amana river were sampled in a 0.75-km transect laid along the river on the left side of the road from Menna to Bidire. The transects were laid parallel 1.5–4 km from the road on both sides. Quadrats were laid at every 250 m along transect lines, which are laid 400 m apart. All woody plant species including trees and shrubs were recorded in 20 m × 20 m quadrats while herbaceous species were recorded in two 1 m × 1 m subplots that are subjectively placed within the main quadrat. For sampling in woodland vegetation, a 20 m × 20 m quadrat could be considered based on the concept of minimal area (Kent and Coker 1992). All plant species were counted at individual level within each main quadrat and subplot. Height and diameter

at breast height (DBH) were measured for any woody plant species with height ≥ 2 m and DBH ≥ 2 cm. Individuals having height < 2 m and DBH < 2 cm were counted. Height and DBH measurement was made using calibrated bamboo stick and diameter tape, respectively. Where slope, topography, and canopy made height measurement difficult, it was visually estimated. Altitude and geographical co-ordinates were measured for each quadrat using Garmin eTrex GPS. Slope was measured using Suunto Clinometer. Every plant species encountered in each quadrat was recorded using scientific names. Vernacular names were also recorded whenever possible. For those species difficult to identify in the field, plant specimens were collected, pressed and brought to the National Herbarium of Ethiopia (ETH), Department of Biology, Addis Ababa University for taxonomic identification. Published volumes of the Flora of Ethiopia and Eritrea (Hedberg and Edwards 1989; Edwards et al. 1995; Hedberg and Edwards 1995; Edwards et al. 1997; 2000; Hedberg et al. 2003; 2004; 2006) were used to identify plant specimens. Voucher specimens were kept at ETH.

Data analysis

A hierarchical cluster analysis was performed using PC - ORD for windows version 4.20 (McCune and Mefford 1999) to classify the vegetation into plant community types. Abundance data (the number of individuals) of the species were used for cluster analysis. The decision on the number of plant communities was based on the multi-response permutation procedure (MRPP). The identified groups were also tested for the hypothesis of no difference among the groups using the same technique. MRPP is a nonparametric procedure for testing the hypothesis of no difference between two or more groups of entities (McCune and Mefford 1999). Thus, statistical validity of the identified groups was evaluated using MRPP. The plant communities were named after one or two dominant indicator species, as selected by the relative magnitude of their indicator values (Table 1). Species indicator values were calculated using the method of Dufrene and Legendre (1997) to determine indicator species. Indicator values are measures of the faithfulness of occurrence of a species in a particular group (McCune and Mefford 1999). In this study, a species is considered as an indicator of a group when its indicator value is significantly higher at $p < 0.05$. Shannon-Wiener diversity index, species richness and Shannon's evenness were computed to describe species diversity of the plant community types in the vegetation. Sorensen's similarity coefficient was used to determine the pattern of species turnover among successive communities (Kent and Coker 1992; Krebs 1999). The structure of the vegetation was described using frequency distributions of DBH, height and important value index (IVI). Density and basal area values were computed on hectare basis. Important value indices were computed for all woody species based on their relative density (RD), relative dominance (RDO) and relative frequency (RF) to determine their dominance (Kent and Coker 1992).

The formulae for computing diversity index, similarity coefficient, and IVI were indicated below.

Shannon Wiener diversity (H') and evenness (E) indices:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \qquad (1)$$

where, H' = Shannon diversity index; S = the number of species; P_i = the proportion of individuals or the abundance of the i^{th} species expressed as a proportion of total cover; ln = logbase_n, n = 10

Evenness was calculated as the ratio of observed diversity to maximum diversity using the equation:

$$E = H'/H_{max} \text{ where } H_{max} = \ln S \qquad (2)$$

where, H_{max} is the maximum level of diversity possible within a given population (Kent and Coker 1992).

Sorensen's similarity coefficient:

$$S_s = 2a/(2a+b+c) \qquad (3)$$

where, S_s = Sorensen's similarity coefficient; a = Number of species common to both samples; b = Number of species in sample 1; c = Number of species in sample 2

Important value index (IVI):

IVI = relative density (abundance) + relative dominance (basal area) + relative frequency (4)

where, relative density = the number of all individuals of a species/the total number of all individuals (DBH ≥ 2 cm) × 100; relative basal area = the basal area of a species/total basal area × 100 (DBH ≥ 2 cm) and relative frequency = the number of plots where a species occurs/ the total occurrence of all species in all of the plots × 100. Basal area was calculated using DBH as follows:

$$\text{Basal area} = \text{II}d^2/4 \qquad (5)$$

where II = 3.14; d = DBH (m).

Results and discussion

Floristic composition

A total 171 vascular plant species, belonging to 53 families and 117 genera were recorded from the vegetation (Appendix 1). Fabaceae was the most dominant family with 13 genera and 26 species. Asteraceae, Lamiaceae and Anacardiaceae were the second dominant families with eight species each, and they had six, six and three genera, respectively. The third species rich families were Tiliaceae, Combretaceae, Burseraceae and Malvaceae with seven, six, six and six species, and two, two, two and four genera, respectively. Thirty families were represented by more than one species while the rest 23 were represented by a

single species each. The dominance of Fabaceae was reported from similar vegetation studies (Gemedo 2004; Teshome et al. 2004; Anteneh 2006; Negusse 2006; Getachew et al. 2008). This may imply that the environmental conditions in these areas are more favourable for this family. Of the total species recorded, 56 (32.7%) were trees; 47 (27.5%) shrubs; 55 (32.2%) herbs other than grasses; 9 (5.3%) woody climbers and 4 (2.3%) were grasses.

Compared to similar vegetation types in Ethiopia, the species richness is lower than Savanna grassland and woodland vegetation in Nechisar National Park (199 species, Tamrat 2001); dry land vegetation of Wello (216 species, Getachew et al. 2008); vegetation in Sof Umer area of Bale (213 species, Negusse 2006); vegetation of Babile Elephant Sanctuary (237 species, Anteneh 2006). It is more or less comparable with that was reported for the vegetation of Chencha highlands (174 species, Desalegn and Zerihun 2005). Out of the total species, *Kirkia burgeri* has been registered in the IUCN red data list of Ethiopia and Eritrea (Vivero et al. 2005) qualifying for vulnerable category.

Table 1. Indicator values of each species for each group and Monte Carlo test of significance observed for each species.

Species	1	2	3*	P-value	Species	1	2	3*	P-value
Group 1					*Pyrenacantha malvifolia*	3	62	0	0.006
Dalbergia microphylla	58	2	6	0.028	*Ochna inermis*	5	63	0	0.006
Combretum aculeatum	33	0	0	0.085	*Grewia mollis*	0	48	0	0.009
Terminalia brownii	30	0	6	0.148	*Boscia angustifolia*	0	46	0	0.013
Euclea racemosa	39	0	26	0.162	*Kirkia burgeri*	2	37	0	0.033
Canthium pseudosetiflorum	21	0	0	0.197	*Grewia villosa*	6	37	0	0.051
Rhus natalensis	29	0	9	0.275	*Psydrax schimperiana*	0	24	0	0.067
Grewia ferruginea	15	0	0	0.381	*Senna obtusifolia*	0	23	0	0.069
Diospyros abyssinica	14	5	0	0.474	*Acacia bussei*	0	25	0	0.079
Balanites aegyptiaca	12	0	0	0.572	*Ficus sycomorus*	0	25	0	0.085
Tamarindus indica	9	0	0	0.626	*Syzygium guinense* subsp. *guinense*	0	25	0	0.085
Ximenia americana	16	0	11	0.647	*Breonadia salicina*	0	25	0	0.085
Lannea rivae	9	0	0	0.658	*Acacia mellifera*	26	47	2	0.1
Commiphora africana	23	7	14	0.66	*Acacia robusta*	1	18	0	0.138
Lannia schimperi	9	0	0	0.661	*Delonix elata*	1	20	0	0.138
Maytenus gracilipes	12	0	3	0.679	*Sesamothamnus rivae*	2	19	0	0.141
Entada leptostachya	10	0	3	0.703	*Berchemia discolor*	4	19	0	0.189
Maerua triphylla	6	0	0	0.822	*Commiphora myrrha*	0	17	2	0.226
Boswelia neglecta	6	0	0	0.832	*Commiphora baluensis*	16	28	0	0.232
Flacourtia indica	3	0	0	1	*Acacia tortlis*	3	20	0	0.236
Olea europaea	3	0	0	1	*Lannia triphala*	0	17	13	0.427
Ziziphus abyssinica	3	0	0	1	*Croton dichogamus*	6	13	0	0.439
Ziziphus spina-christii	3	0	0	1	*Haplocoelum foliolosum*	16	16	0	0.455
Acacia albida	3	0	0	1	Group 3				
Combretum adenogonium	3	0	0	1	*Combretum molle*	2	0	85	0.001
Cordia africana	3	0	0	1	*Combretum collinum* subsp. *Binderianum*	2	0	78	0.002
Maytenus addat	3	0	0	1	*Acacia seyal*	5	0	76	0.003
Pappea capensis	5	0	5	1	*Ocimum urticifolium*	3	0	73	0.003
Ruttya fruticosa	3	0	0	1	*Gardenia ternifolia*	0	0	62	0.008
Teclea nobilis	3	0	0	1	*Ozoroa insignis*	0	0	48	0.01
Withania somnifera	3	0	0	1	*Ziziphus mauritania*	1	0	55	0.012
Grewia velutina	3	0	1	1	*Harrisonia abyssinica*	1	0	61	0.013
Piliostigma thonningii	3	0	0	1	*Terminalia polycarpa*	5	14	58	0.018
Secamone parviflora	3	0	0	1	*Acacia etbaica*	0	0	32	0.04
Strochynos mitis	3	0	0	1	*Ormocarpum trichocarpum*	7	0	41	0.052
Dobera glabra	3	0	0	1	*Carissa spinarum*	0	0	16	0.146
Group 2					*Acacia nilotica*	11	0	28	0.202
Grewia bicolar	11	75	2	0.001	*Rhus vulgaris*	0	0	16	0.225
Acacia brevispica	2	89	1	0.001	*Gomphocarpus fruticosus*	0	0	8	0.31
Acacia senegal	1	93	1	0.001	*Asparagus flagellaris*	0	0	8	0.328
Asparagus falcatus	1	86	4	0.001	*Stereospermum kuntianum*	0	0	7	0.381
Solanum incanum	2	84	0	0.002	*Dichrostachys cinerea*	18	0	27	0.415
Commiphora habessinica	1	70	0	0.002	*Abutilon figarianum*	1	0	6	0.543
Grewia velutina	0	96	0	0.002	*Steganotaenia araliacea*	3	0	10	0.708
Ruspolia seticalyx	2	61	0	0.003	*Dodonia angustifolia*	3	0	5	0.768

* The number of 1,2,3 indicate groups (communities); P is a probability value to decide whether a species is a significant indicator of a group.

Plant community types

Three plant community types were identified from the hierarchical cluster analysis (Fig. 2). The analysis was based on the abundance data of the species. The data matrix contained 50 plots and 87 woody species. One plot (plot no. 1), which did not fit into any cluster was recognized as an outlier and was not considered in the plant community analysis. The description of the community types identified is given below.

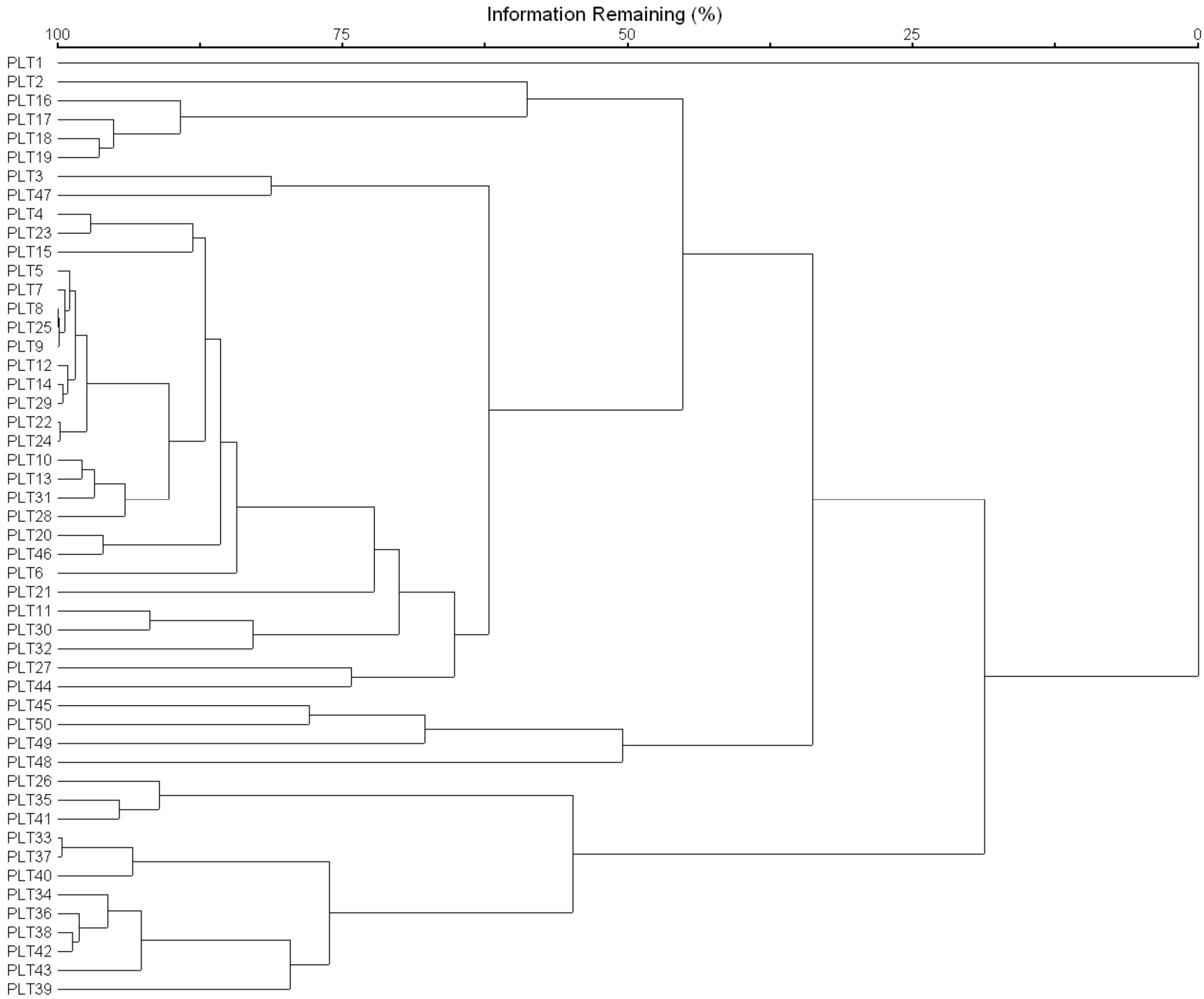

Fig. 2 Dendrogram of the vegetation data obtained from hierarchical cluster analysis.

Dalbergia microphylla community

This community was found between 1 039 and 1 279 m a.s.l. It represented 33 plots and 137 species. Relatively, most of species and plots investigated in the study were associated to the community. All the plots were situated across the landscape except one, which belongs to the riverine vegetation along Melka Amana river. *D. microphylla* is the only indicator species of the community. Other woody species including trees, shrubs and lianas were associated to the community (Table 2). The tree layer was dominated by *Tamarindus indica*, *D. microphylla, Terminalia brownii, Diospyros abyssinica and Faidherbia albida. Combretum aculeatum, Euclea racemosa* and *Grewia velutina* were the dominant species at shrub layer, while *Barleria acanthoides* and *Chlorophytum gallabatense* were the dominant herbs. *Entada leptostachya* and *Cissus quadrangularis* were the common woody climbers. *Tetrapogon tenellus* and *Perotis patens* were the common grass species recorded from the herb layer. High number of small sized individuals was observed for *Maytenus senegalensis* on sloppy hills, implying that the species has relatively good regeneration.

D. microphylla was reported to occur on sandy soils at relatively higher elevations in Borana lowlands (Gemedo 2004). This concurs with the current result that *D. microphylla* community covered a wide range of areas dominated by sandy soils. The

vegetation under this community constituted various land forms such as small gorges, rocky hills and flat terrain. *Euclea racemosa* was observed forming patches of dense shrubland. The situation of this community at intermediate altitudes (i.e. 1 039–1 279 m.a.s.l.) might have contributed to the observed high species richness and diversity. The relatively high regeneration of *M. senegalensis* observed in this community may result from the optimum environmental conditions associated with intermediate elevations.

Table 2. Species richness, evenness, and Shannon-Wiener diversity index of the plant community types

Communities*	Species richness	Diversity index (H')	Evenness (H'/H_{max})	H_{max}
G. bicolar-A. brevispica community	57	3.323	0.822	4.043
Dalbergia microphylla community	137	3.864	0.785	4.920
Combretum molle - Combretum collinum community	74	3.304	0.765	4.317

* Communities are arranged in ascending order of altitude.

Grewia bicolar- Acacia brevispica community

This community was found relatively at lower altitudes between 1 035 and 1 083 m.a.s.l. It comprised of four plots and 57 species. All the plots were sampled from what was commonly known as *Acacia-Commiphora* woodland except one that belonged to the riverine vegetation along Melka Amana river. This community was characterized by 13 indicator species. These include *Grewia bicolar, Acacia brevispica, Acacia senegal, Asparagus falcatus, Solanum incanum, Commiphora habessinica, Grewia velutina, Ruspolia seticalyx, Pyrenacantha malvifolia, Ochna inermis, Grewia mollis, Boscia angustifolia,* and *Kirkia burgeri.* Associated species forming the tree layer include *Commiphora baluensis*, *Acacia tortlis*, *Acacia mellifera*, *Acacia bussei, Delonix elata, Commiphora myrrha,* and *Acacia robusta.* The shrub layer was dominated by *O. inermis*, *R. seticalyx*, *G. bicolar*, *G. mollis*, *Croton dichogamus,* and *A. brevispica.* Herbaceous species include *Achyranthes aspera, Barleria acanthoides, Acanthospermum hispidum,* and *Chlorophytum gallabatense. Pyrenacantha malvifolia* was the dominant liana in this community. *Dignathia hirtella* was the common grass species.

The dominant indicator species of this community, *G. bicolar* and *A. brevispica,* were reported to occur on clay soils and sandy soils, respectively, in Borana lowlands (Gemedo 2004). On the contrary, both the species occurred on sandy soils in this study. *A. brevispica* was reported to be a dominant indicator of a community in the vegetation of Gamo Gofa zone (Teshome et al. 2004). *G. bicolar* was also reported to be a characteristic species of a community in the dry land vegetation of Wello at a mean altitude of 1 260 m (Getachew et al. 2008).

This community was found at the periphery of the dense woodland located at northeast of Melka Amana village. Livelihood activities such as cultivation and charcoal making were quite common in the vegetation where this community occurred. The fact that it was located at lower altitudes and its liability to such disturbances made this community a distinct unit in species composition. The finding coincided more or less with the traditional description of the vegetation as *Acacia-Commiphora* woodland because many *Acacia* and *Commiphora* species are associated to the group.

Combretum molle-Combretum collinum community

This community was located between 1 256 and 1 293 m.a.s.l, relatively, at higher altitudes. Twelve plots and 74 species were associated to the community. The community had 10 indicator species with significant indicator values. These include *Combretum molle, Combretum collinum* subsp. *binderianum, Acacia seyal, Ocimum urticifolium, Gardenia ternifolia, Ozoroa insignis, Ziziphus mauritiana, Harrisonia abyssinica, Terminalia polycarpa* and *Acacia etbaica* (Table 2). Other species associated to the community at tree layer include *Acacia nilotica*, *Stereospermum kunthianum* and *Dichrostachys cinerea. Carissa spinarum, Ormocarpum trichocarpum, Rhus vulgaris, Asparagus flagellaris* and *Gomphocarpus fruticosus* were the common species at shrub layer with *Harrisonia abyssinica* as the dominant species. *Ocimum urticifolium* and *Ocimum froskolei* dominate the sub-shrub layer of the community. The herbaceous layer is dominated by *Gnidia stenophylla*, *Barleria acanthoides* and grass species such as *Tetrapogon tenellus* and *Perotis patens.*

This community was a very distinct unit characterized by dense woodland vegetation on undulating flat terrain. Tree cutting for construction and charcoal making was more prevalent in the vegetation where this community occurs. It was also noticed that large hectares of the vegetation was being converted to agricultural land. Human settlement and livestock population appear to have influenced several aspects of the vegetation such as regeneration and recruitment.

The designation and description of this community was in agreement with the traditional description of the vegetation as *Combretum - Terminalia* woodland, because *Combretum* and *Terminalia* species were indicators of the community (Table 2). *Combretum molle* was reported to be an indicator species of communities from the vegetation of Gamo Gofa zone (Teshome et al. 2004) as well as Chencha highlands relatively at higher altitudes (Desalegn and Zerihun 2005). It appeared that this species was widespread in its distribution.

The current analyses of plant communities have yielded plot 1 as an outlier, i.e., it did not show sufficient similarity with any one of the recognized community types. As a result, it was recognized as a separate group. It turned as an outlier probably because of the unusually high abundance of the species *Acacia brevispica* and *Ruttya fruticosa.* This plot is composed of species including *Kirkia burgeri, Commiphora baluensis, Euclea racemosa, Dalbergia microphylla, Acacia mellifera, Ochna inermis, Combretum molle, Acacia brevispica, Boscia senegalensis, Maerua triphylla, Croton dichogamus, Maytenus gracilipes,* and *Diospyros abyssinica. Pyrenacantha malvifolia* was the dominant liana whereas *Dignathia hirtella* and *Ehrharta erecta* form the herbaceous layer.

Results of the indicator species analysis for determining the degree to which species were associated with the different groups are presented in Table 1. Species are listed by group af-

finity in the ascending order of the probability values. Bold values indicate significant indicator values ($p < 0.05$) in each group. In all the communities, species with high indicator values are those that were easily observed in the field repeating themselves in associations. Thus, the identified groups more or less coincide with the natural association that can be observed in the vegetation.

Species richness, evenness and diversity of the plant community types

Species diversity, richness and evenness showed gradual change among communities as altitude increases (Table 2). The community *D. microphylla* type was characterized by the highest species richness and diversity and the second highest evenness while the community *G. bicolar – A. brevispica* type was found to have the least species richness but the highest evenness and the second highest species diversity. On the other hand, the community *C. molle - C. collinum* exhibited the least species diversity as well as evenness but the second highest species richness. The species richness and diversity showed a bell - shaped pattern along altitudinal gradient with a peak at intermediate altitudes and declining pattern towards the lower and upper altitudes. This may imply that optimal conditions of environmental factors are associated to intermediate altitudes. A similar pattern for species richness was reported from the vegetation of Chencha highlands in southern Ethiopia (Desalegn and Zerihun 2005). The result also agreed with the commonly held view that species richness tends to peak at intermediate elevations (Brown 2001; Grytnes and Vetaas 2002; Bhattarai and Vetaas 2003; Watkins et al. 2006; Hegazy et al. 2007; Brinkmann et al. 2008). On the contrary, Gemedo (2004) reported a positive correlation of species richness with altitude in his quantitative analysis of relationships between environmental gradients and vegetation in Borana lowlands, southern Ethiopia. Similarly, Sánchez-González and López-Mata (2005) found that species richness and diversity tend to increase with altitude in the northern Sierra Nevada, although the trend is not universal. However, much of the information in literatures agrees on the fact that maximum species richness occurs at lower to intermediate elevations.

Similarity among plant community types

Sorensen's similarity coefficient among communities was presented in Table 3. Similarity in species composition varied among communities along altitudinal gradient. The community *G. bicolar - A. brevispica* shared few number of species with communities *D. microphylla* (47%) and *C. molle - C. collinum* (27%). On the other hand, the community *D. microphylla* shared 53% of species recorded in the current study with the community *C. molle - C. collinum* while it shared 47% with the community *G. bicolar- A. brevispica*. The relative discontinuity in species composition between communities *D. microphylla* and *G. bicolar - A. brevispica*, and *G. bicolar- A. brevispica* and *C. molle - C. collinum* could be attributed to the marked transition in altitude among these communities from low altitude where the community *G. bicolar - A. brevispica* was located to the intermediate and relatively higher altitudes where communities *D. microphylla* and *C. molle - C. collinum* were situated. The dissimilarity in species composition among communities appeared to arise mainly from the community *G. bicolar - A. brevispica*. This could be attributed to the location of this community at lower altitudes. Such an altitudinal transition governs microclimatic conditions such as temperature, radiation, moisture and the nature of substrate which in turn influence plant growth and recruitment (Teshome et al. 2004; Tadesse et al. 2008).

Table 3. Sorensen's coefficient of similarity among communities along altitudinal gradient

Altitudinal ranges (m)	Communities	Number of species included in coparison	Number of species in common	Sorensen's coefficient of similarity
1035-1083/1039-1279	*G. bicola r- A. Brevispica / D. microphylla*	79	24	47
1039-1279/1256-1293	*D. microphylla / C. molle-C. collinum*	78	28	53
1035-1083/1256-1293	*G. bicolar - A. Brevispica / C. molle-C. collinum*	63	10	27

The result is more or less in agreement with previous reports such as Kumelachew and Tamrat (2002), Teshome et al. (2004), and Desalegn and Zerihun (2005) where altitude was identified as the most important environmental factor resulting in major differences among community types. On the other hand, the observed differences in the species composition of the plant communities may also be attributed to other environmental variables such as soil properties, moisture and aspect although no detailed studies of these parameters were undertaken. Last but not least, anthropogenic impacts such as deforestation (Fig. 3) and intensive livestock grazing were observed in the vegetation with more severity in areas where the plant communities *G. bicolar - A. brevispica* and *C. molle - C. Collinum* were found.

Fig. 3 Deforestation in the wood land vegetation

Community-environment relationships

Altitude and slope were the two environmental variables that were averaged for each community type (Table 4). In order to determine significant differences in these variables among communities, Tukey's pairwise comparison was used. The mean

values for altitude were highly variable among communities (Table 4). Thus, the three plant communities identified in this study varied in altitude in which they occur. On the other hand, mean values for slope did not vary among plant communities. This shows that altitude is one of the most important environmental factors that determine species composition and distribution of plant communities across landscapes although there are overlaps among some community types. Similar results were reported by Lisanework and Mesfin (1989); Kumelachew and Tamrat (2002); Teshome et al. (2004); Desalegn and Zerihun (2005); Getachew et al. (2008) and Tadesse et al. (2008)

Table 4. Tukey's pairwise comparisons between environmental variables and community types

Plant communities	Environmental variables	
	Altitude (m)	Slope (%)
D. microphylla	1182 ± 67.6^a	1.94 ± 1.72^a
G. bicolar – A. brevispica	1066.5 ± 21.5^b	0.92 ± 0.43^a
C. molle – C. collinum	1277.6 ± 12.9^c	0.97 ± 0.92^a

The numbers in the rows of variables show M ± standard deviation. Means that are not significantly different from each other at $p < 0.05$ are marked with the same letter.

Vegetation structure

DBH and height class distributions

In the current study, DBH and height class distribution of all individuals in different size classes showed an inverted J-shape distribution (Fig. 4). This is a general pattern of normal population structure where the majority of the species had the highest number of individuals at lower DBH and height classes with gradual decrease towards both high DBH and height classes. This suggests good reproduction and recruitment potential of the vegetation. However, this pattern does not depict the general trends of population dynamics and recruitment processes of a given species. Analysis of population structures for each individual tree and shrub species could provide more realistic and specific information for conservation measures.

Diameter class distribution of selected tree species demonstrated various patterns of population structure, implying different population dynamics among species (Fig. 5). An inverted J-shaped distribution was exhibited by *C. africana, D. microphylla* and *T. polycarpa,* representing relatively a healthy regeneration of the species. On the other hand, other distribution patterns such as broken J-shaped (*C. baluensis*); broken inverted J-shaped (*A. mellifera* and *A. tortlis*); bell - shaped (*C. molle*, *A. senegal* and *A. seyal*) and irregularly broken up structure (*T. brownii)* were also recognized (Fig. 5). Comparable results were reported for *A. mellifera* and *C. baluensis* from the vegetation of Boke salt house in Borana lowlands, southern Ethiopia (Teshome 2006). *A. mellifera, A. tortlis, C. baluensis* and *T. brownii* lacked individuals in some diameter classes because of selective removal of the species for construction and fuel wood. On the other hand, *A. tortlis, A. mellifera, C. africana,* and *D. microphylla* exhibited high number of individuals in the lower diameter classes. Such pattern indicates more or less good reproduction followed by either removal or death of older individuals.

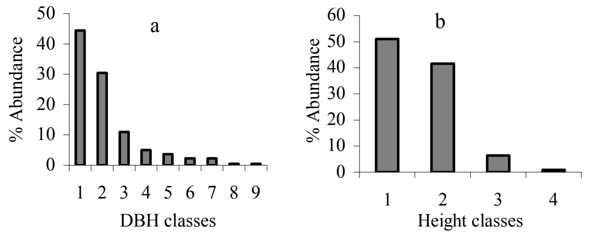

Fig. 4 Percentage distribution of all individuals (a) in DBH classes (DBH classes: 1= <5 cm; 2 = 5–9.9 cm; 3 = 10–14.9 cm; 4 = 15–19.9 cm; 5 = 20–24.9 cm; 6 = 25–29.9 cm; 7 = 30–34.9 cm; 8 = 35–39.9 cm; 9 = ≥ 40 cm) and **(b) in height classes** (Height classes: 1 = ≤ 5 m; 2 = 5.1–10 m; 3 = 10.1–15 m; 4 = >15 m)**.**

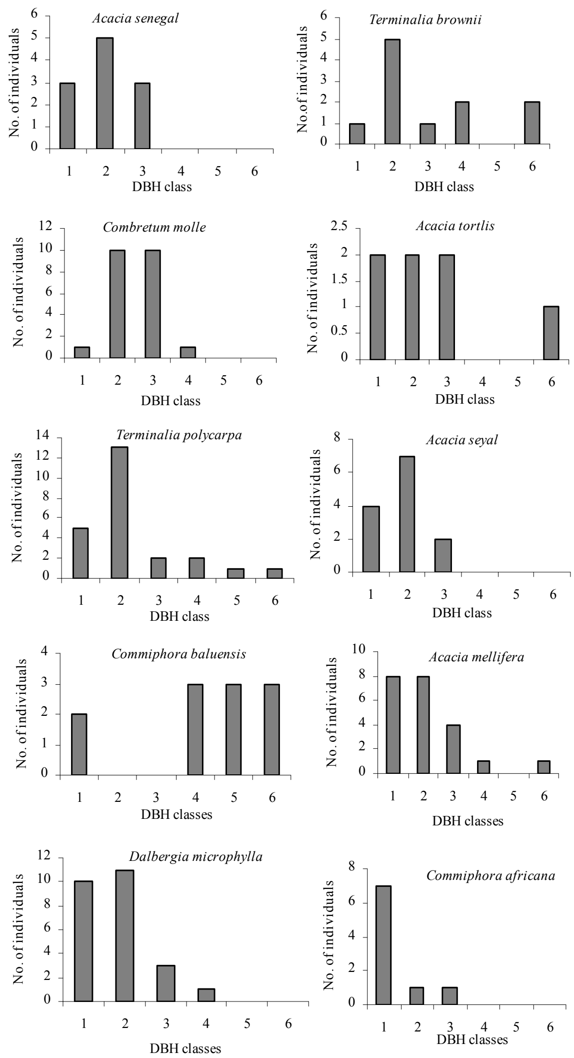

Fig. 5 Patterns of frequency distribution of selected tree species over DBH classes (DBH classes: 1= < 5 cm; 2 =5–9.9 cm; 3 = 10–14.9 cm; 4 =15–19.9 cm, 5 = 20–24.9 cm, 6 = ≥ 25 cm)**.**

Most of the species with missing individuals in some DBH

classes occur in communities *G. bicolar- A. brevispica* and *C. molle-C. collinum.* The community *G. bicolar – A. brevispica* was situated at the periphery of the vegetation where disturbance in the form of cultivation is encroaching into the vegetation. Disturbance was also common in the *C. molle - C. collinum* community in the form of selective cutting for charcoal making and construction wood. Besides, these species were commonly preferred for fuel wood and construction. Thus, the complete absence of individuals in some diameter classes might have resulted from selective cutting and hampered regeneration of the species. The hampered regeneration could be attributed mainly to grazing or trampling by livestock that was a common phenomenon in the vegetation.

Important value index (IVI)

The output of IVI analysis showed that *T. polycarpa* (18.20), *C. molle* (17.05), *A. mellifera* (16.58), *E. racemosa* (13.91) and *C. baluensis* (11.27) were the first five most dominant species (Table 5). These species constituted 25.7% of the total importance value index, while the majority of the species (90.4%) had important value indices of less than 10 (Fig. 6). Note that *C. molle* and *T. polycrpa* were also indicator species for the plant community *C. molle – C. collinum,* which signified their overall ecological importance.

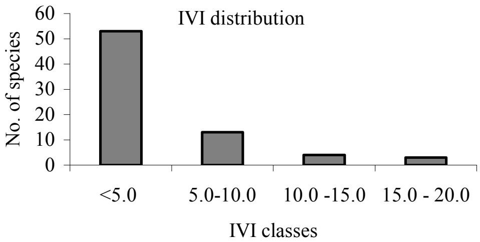

Fig. 6 Distribution of the IVI among species

Density, frequency and dominance

Analysis of relative density showed that *C. molle*, *E. racemosa* and *T. polycarpa* were the top three abundant species (Table 5). *A. mellifera*, *T. polycarpa* and *D. microphylla* were the most frequent woody species. Calculation of relative basal area showed that *T. indica*, *C. baluensis* and *T. poycarpa* were the most dominant species. *F. sycomorus* has attained the highest values of basal area and IVI, but it was excluded from dominant species as it had the least frequency and density (Table 5).

Conclusions and recommendations

In the present study, floristic composition, plant community types and patterns of community transition were determined for the woodland vegetation around Dello Menna. Fabaceae was found to be the most dominant family followed by Asteraceae, Lamiaceae, Anacardiaceae and Tiliaceae. Trees and herbs were the dominant growth forms, while grasses were least represented. Of the total species recorded, *Kirkia burgeri* has been registered in the IUCN red data list under the vulnerable category.

Table 5. Important value index (IVI) of woody plant species from the woodland vegetation.

Species	RD	RDO	RF	IVI	GF
Ficus sycomorus	0.02	24.40	0.16	24.57	T
Terminalia polycarpa	7.92	5.30	4.98	18.20	T
Combretum molle	9.91	3.72	3.43	17.05	T
Acacia mellifera	7.90	3.08	5.61	16.58	T
Euclea racemosa	8.42	0.82	4.67	13.91	S
Commiphora baluensis	0.85	7.77	2.65	11.27	T
Grewia bicolar	5.68	1.19	4.36	11.23	S
Dalbergia microphylla	3.81	2.09	4.98	10.88	T
Tamarindus indica	1.30	7.91	0.47	9.68	T
Acacia senegal	5.30	1.12	2.96	9.37	T
Combretum collinum subsp. *Binderianum*	3.31	2.41	2.96	8.68	T
Acacia nilotica	0.76	3.17	2.49	6.41	T
Acacia seyal	2.01	1.10	3.27	6.38	T
Combretum aculeatum	4.16	0.20	1.71	6.07	S
Dacrostachys cinerea	2.81	0.34	2.80	5.95	T
Kirkia burgeri	0.64	4.15	0.93	5.73	T
Commiphora africana	2.10	0.29	3.27	5.66	T
Acacia brevispica	2.96	0.05	2.49	5.50	S
Rhus natalensis	2.13	0.52	2.80	5.46	S
Ochna inermis	2.96	0.06	2.18	5.20	S
Terminalia brownii	0.97	1.72	2.49	5.18	T
Pappea capensis	0.24	2.77	0.93	3.94	T
Grewia velutina	2.29	0.22	1.25	3.76	S
Lannia triphala	0.83	1.69	1.25	3.76	T
Acacia tortlis	0.38	2.04	1.25	3.66	T
Ximenia americana	1.63	0.16	1.87	3.66	S
Harrisonia abyssinica	1.14	0.26	2.02	3.42	S
Ormocarpum trichocarpum	0.97	0.09	2.34	3.40	S
Lannia schimperi	0.14	2.64	0.47	3.25	T
Acacia robusta	0.28	2.55	0.31	3.14	T
Ziziphus mauritania	1.14	0.23	1.56	2.92	T
Haplocoelum foliolosum	0.85	0.40	1.56	2.81	T
Diospyros abyssinica	0.80	0.73	1.25	2.78	T
Gardenia ternifolia	0.87	0.04	1.56	2.48	T
Croton dichogamus	1.25	0.04	0.93	2.23	S
Berchemia discolor	0.35	0.93	0.93	2.22	T
Entada leptostachya	1.21	0.03	0.93	2.17	C
Syzygium guinense subsp. *guinense*	0.35	1.56	0.16	2.07	T
Ozoroa insignis	0.26	0.71	1.09	2.06	T
Dobera glabra	0.02	1.83	0.16	2.01	T
Psydrax schimperiana	0.66	0.22	1.09	1.97	S
Delonix elata	0.14	1.51	0.31	1.96	T
Strochynos mitis	0.14	1.67	0.16	1.96	T
Maytenus senegalensis	0.54	0.31	1.09	1.94	S
Acacia etbaica	0.40	0.73	0.78	1.91	T
Canthium pseudosetiflorum	0.76	0.01	1.09	1.85	S
Grewia mollis	1.04	0.31	0.47	1.82	S
Grewia villosa	0.28	0.02	1.40	1.70	S
Lannea rivae	0.12	1.01	0.47	1.59	T
Acacia bussei	0.02	1.26	0.16	1.44	T
Commiphora habessinica	0.26	0.22	0.93	1.41	T
Rhus vulgaris	0.54	0.08	0.62	1.25	S
Boscia angustifolia	0.57	0.05	0.62	1.24	S
Breonadia salicina	0.02	0.98	0.16	1.16	T
Sesamothamnus rivae	0.17	0.34	0.62	1.13	T
Grewia ferruginea	0.26	0.04	0.78	1.08	S
Grewia sulcata	0.71	0.04	0.31	1.06	S
Carissa spinarum	0.57	0.02	0.47	1.05	S
Total of other species (16)	1.86	0.89	5.01	7.75	
Total	100.00	100.00	100.00	300.00	

RD = Relative density; RDO = Relative dominance; RF = Relative frequency; T= tree; S = shrub; C= climber

The vegetation was grouped into three different plant commu-

nity types. The classification produced plant communities that match more or less with the natural associations that can be recognized in the field. Species richness and diversity varied along altitudinal gradient, and among the community types with a peak at intermediate altitudes. *D. microphylla* community exhibited the highest species richness and diversity index. The least species richness was found in *G. bicolar – A. brevispica* community with the highest evenness. The community *C. molle - C. collinum* had the second highest species richness and the least diversity index and evenness. Species turn over among communities also followed altitudinal gradient. Therefore, it appeared that altitude influenced species composition, diversity and the distribution of community types in the study area. The observed variation in species composition, diversity and distribution among communities could also be attributed to other environmental factors such as soil chemical and physical properties, moisture and aspect. Anthropogenic factors such as intensive livestock grazing and selective cutting, which were observed in most parts of the vegetation, might have also resulted in the observed differences. Analysis of population structure of the most common species showed that only few species exhibit normal population structure, implying hampered regeneration and selective removal of some individuals.

The results of this study can contribute towards understanding of the patterns of plant species diversity of the vegetation, which is of considerable importance for its conservation. From the results of this study, it is recommended that detailed ecological studies are vital concerning the species composition, diversity and distribution of the possible plant community types in relation to other environmental factors such as soil properties, which were not the subject of this study. This would help in capitalizing on the current finding through generation of more quantitative data to clearly identify the environmental factors responsible for the observed pattern. Detailed ethnobotanical studies are also required to explore the wealth of indigenous knowledge on the diverse uses of plants and their implication in conservation. The current devastation of the woodland vegetation needs to be arrested through the collaborative effort of the government and the local community.

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References

Abate A, Tamrat B, Sebsebe D. 2006. The undifferentiated afromontane forest of Denkoro in the central highland of Ethiopia: A floristic and structural analysis. *Ethiop J Sci*, **29**: 45−56.

Anteneh B. 2006. *Floristic Description and Ethnobotanical Study of the Natural Vegetation in the Babile Elephant Sanctuary, Ethiopia*. MSc. Thesis. AAU, Addis Ababa.

Bhattarai KR, Vetaas OR. 2003. Variation in plant species richness of different life forms along a subtropical elevation gradient in the Himalayas, east Nepal. *Glob Ecol Biogeog,* **12**: 327−340.

Brinkmann K, Patzelt A, Dickhoefer U, Schlecht E, Buerkert A. 2009. Vegetation patterns and diversity along an altitudinal and a grazing gradient in the Jabal al Akhdar mountain range of northern Oman. *J Ari Env*, **73**: 1035−1045.

Brown JH. 2001. Mammals on mountainsides: elevational patterns of diversity. *Glob Ecol Biogeog,* **10**: 101−109.

Daniel G. 1977. *Aspects of Climate and Water budget in Ethiopia*. A technical Monograph. Addis Ababa University. 39p.

Demel T. 1992. Human impact on a natural montane forest in southeastern Ethiopia. *Mount Res Dev,* **12**: 393−400.

Demel T. 2005. Seed and regeneration ecology in dry Afromontane forests of Ethiopia: I. Seed production – population structures. *J Trop Ecol,* **46**:29−44.

Desalegn W, Zerihun W. 2005. Vegetation of Chencha highlands in southern Ethiopia. *Ethiop J Sci*, **28**: 109−118.

Dufrene M, Legendre P. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecol Mono*, **67**: 345−366.

Edwards S, Mesfin T, Hedberg I. 1995. Flora of Ethiopia and Eritrea, Vol. 2(2). The National Herbarium, Addis Ababa.

Edwards S, Mesfin T, Sebsebe D, Hedberg I. 2000. Flora of Ethiopia and Eritrea, Vol. 2(1). The National Herbarium, Addis Ababa.

Edwards S, Sebsebe D, Hedberg I. 1997. Flora of Ethiopia and Eritrea, Vol. 6. The National Herbarium, Addis Ababa.

Ermias L, Ensermu K, Tamrat B, Haile Y. 2008. Plant species composition and structure of the Mana Angetu mosit montane forest, south-eastern Ethiopia. *J East Afrc Natur hist,* **97**(2): 165−185.

EWNHS (Ethiopian Wildlife and Natural History Society). 1996. *Important Bird Areas of Ethiopia. A First Inventory*. EWNHS, Addis Ababa.

Feyera S, and Denich M. 2006. Effects of wild coffee management on species diversity in the Afromontane rainforests of Ethiopia. *For Ecol Manage*, **232**: 68−74.

Feyera S. 2006. *Biodiversity and Ecology of Afromontane Rainforests with Wild Coffea arabica L. Populations in Ethiopia*. Ecology and Development Series No. 38. Center for Development Research, University of Bonn.

Gemedo D. 2004. *Vegetation Ecology, Rangeland Condition and Forage Resources Evaluation in the Borana Lowlands, Southern Oromia, Ethiopia*. Doctoral Dissertation. Georg-August University, Göttingen.

Getachew T, Tamrat B, Sebsebe D. 2008. Dryland woody vegetation along an altitudinal gradient on the eastern escarpment of Welo, Ethiopia. *Ethiop J Sci*, **31**: 43−54.

Grytnes JA, Vetaas OR. 2002. Species Richness and Altitude: A comparison between Null Models and Interpolated Plant Species Richness along the Himalan Altitudinal Gradient, Nepal. *The American Natural*, **159**: 294−304.

Haile Y, Ensermu K, Tamrat B, Ermias L. 2008. Floristic composition and structure of the dry afromontane forest at Bale Mountains National Park, Ethiopia. *Ethiop J Sci*, **31**: 103−120.

Hedberg I, Edwards S, Sileshi N. 2003. *Flora of Ethiopia and Eritrea, Vol. 4(1)*. The National Herbarium, Addis Ababa.

Hedberg I, Edwards S. 1989. *Flora of Ethiopia, Vol. 3*. The National Herbarium, Addis Ababa.

Hedberg I, Edwards S. 1995. *Flora of Ethiopia and Eritrea, Vol. 7*. The National Herbarium, Addis Ababa.

Hedberg I, Ensermu K, Edwards S, Sebsebe D, Persson E. 2006. *Flora of Ethiopia and Eritrea, Vol. 5*. The National Herbarium, Addis Ababa.

Hedberg I, Friis I, Edwards S. 2004. *Flora of Ethiopia and Eritrea, Vol. 4(2).* The National Herbarium, Addis Ababa.

Hegazy AK, Lovett-Doust J, Hammouda O, Gomaa NH. 2007. Vegetation distribution along the altitudinal gradient in the northwestern Red Sea region. *Comm Ecol,* **8**: 151–162.

Kent M, Coker P. 1992. *Vegetation Description and Analysis*. *A practical approach*. New York: John Wiley and Sons, 363p.

Kitessa H, Tamrat B, Ensermu K. 2007. Floristic and phytogeographic synopsis of a dry Afromontane coniferous forest in the Bale Mountains (Ethiopia): implications to biodiversity conservation. *Ethiop J Sci*. **30**:1–12.

Krebs CJ. 1999. *Ecological Methodology*. Second edition. Addison-Welsey Educational publishers. Inc.

Kumelachew Y, Tamrat B. 2002. Plant community analysis and ecology of Afromontane and transitional rainforest vegetation of southwestern Ethiopia. *Ethiop J Sci*, **25**:155–175.

Lisanework N, Mesfin T. 1989. An Ecological study of the vegetation of the Harenna forest, Bale, Ethiopia. *Ethiop J Sci*, **12**: 63–93.

McCune B, Mefford MJ. 1999. PC-ORD. Multivariate Analysis of Ecological Data.Version 4.20. MjM software, Gleneden Beach, Oregon, USA.

Minassie G, Masresha F. 1996. Plant communities of the Afroalpine vegetation of Sanetti plateau, Bale Mountains, Ethiopia. *Ethiop J Sci,* **19**: 65–86.

Mueller-Dombois D, Ellenberg H. 1974. *Aims and Methods of Vegetation Ecology*. Wiley and Sons, New York, 547 pp.

Negusse T. 2006. *Ecology and Plant Use Diversity in Sof Umer area of Bale, Southeastern Ethiopia*. MSc. Thesis. AAU, Addis Ababa.

Sánchez-González A, López-Mata L. 2005. Plant species richness and diversity along an altitudinal gradient in the Sierra Nevada, Mexico. *Diversity Distrib*, **11**: 567–575.

Sebsebe D, Nordal I, Stabbetorp OE. 2003. Flowers of Ethiopia and Eritrea. Aloes and other Lilies. First edition. Shama Books, Addis Ababa. 227p.

Simon S, Zerihun W. 2006. Comparative floristic study on Mt. Alutu and Mt. Chubbi along an altitudinal gradient. *J Drylan,* **1**(1): 8–14.

Tadesse WG, Borsch T, Denich M, Demel T. 2008. Floristic composition and environmental factors characterizing coffee forests in southwest Ethiopia. *For Ecol Manage,* **255**: 2138–2150.

Tadesse WG, Demel T. 2001. The forest coffee ecosystems: Ongoing crises, problems and opportunities for coffee gene conservation and sustainable utilization. In: *Imperative problems associated with forestry in Ethiopia*, pp. 131-142. Workshop proceedings. Biological Society of Ethiopia, Addis Ababa.

Tadesse WG, Denich M, Demel T. 2002. Human impacts on the *Coffea arabica* gene pool in Ethiopia and the need for its in situ conservation. In: Engels, J.M.M., Rao, V.R., Brown, A.H.D. and Jackson, M.T. (eds), *Managing Plant genetic Diversity*, pp. 237–247, CAB International, USA.

Tadesse WG. 2003. *Vegetation of the Yayu forest in Southwest Ethiopia: Impacts of human use and Implications for In situ conservation of Wild Coffea arabica L. populations*. Ecology and Development Series No. 10. Center for Development Research, University of Bonn.

Tamrat A. 2001. *Floristic Composition and Ecology of the Savannah Grassland and Woodland Vegetation in Nechisar National Park and Its Conservation Status.* MSc. Thesis. AAU, Addis Ababa.

Tamrat B. 1994. Phytosociology and ecology of a humid Afromontane forest on the central plateau of Ethiopia. *J Veg Sc*, **5**: 87–98.

Tesfaye A, Tamrat B, Sebsebe D. 2001. An ecological study of the vegetation of Gambella region, Southwestern Ethiopia. *Ethiop J Sci*, **24**: 213–228.

Teshome S, Demel T, Sebsebe D. 2004. Ecological study of the vegetation in Gamo Gofa zone, southern Ethiopia. *J Tro Ecol,* **45**: 209–221.

Teshome T. 2006. *Study of Woody Plant Species Diversity and Socio-economic Importance of Boke Salt House, A volcanic Crater Lake, in Semi-arid Drylands of Borana, Southern Ethiopia*. MSc. Thesis. AAU, Addis Ababa.

Vivero JL, Ensermu K, Sebesebe D. 2005. *The Red list of Endemic Trees and Shrubs of Ethiopia and Eritrea*. Fauna and Flora International, Cambridge, UK, 23p.

Watkins JR, CardelÚs C, Colwell RK, Moran RC. 2006. Species richness and distribution of ferns along an elevational gradient in Costa Rica. *Amer J Bot*, **93**: 73–83.

Zerihun W, Feoli E, Lisanework N. 1989. Partitioning an elevational gradient of vegetation from southeastern Ethiopia by probabilistic methods. *Vegetatio*, **81**: 189–198.

Zerihun W. 1999. Forests in the vegetation types of Ethiopia and their status in the geographical context. In: Edwards, S., Abebe Demmissie, Taye Bekele and Haase, G. (eds), *Forest Genetic Resources Conservation: Principles, Strategies and Actions*, pp. 1-38. Institute of Biodiversity Conservation and Research and GTZ, Addis Ababa.

Appendix 1. List of plant species recorded from the woodland vegetation around Dello Menna.

Scientific name	Family	Local name*	Habit**
Barleria acanthoides Vahl	*Acanthaceae*	Shishii	H
Barleria parviflora R. Br. ex T. Anders.	*Acanthaceae*	Muka dirii	H
Crabbea velutina S. Moore	*Acanthaceae*	Yemaaruka	H
Ruspolia seticalyx (C.B.CI.) Milne-Redh.	*Acanthaceae*	Dhummuugaa	S
Ruttya fruticosa Lindau	*Acanthaceae*	Dhigrii	S
Actiniopteris radiata (Sw.) Link.	*Actiniopteridiaceae*	Chaffaa	H
Cheilanthes viridis	*Adiantaceae*	Balbaxxee	F
Aloe citrina Carter and Brandham	*Aloaceae*	Hargiisa	H
Achyranthes aspera L.	*Amaranthaceae*	Darguu	H
Pupalia lappacea(L.) A. Juss.	*Amaranthaceae*	-	H
Lannea malifolia (Chiov.) sacl.	*Anacardiaceae*	Cilee	T
Lannea rivae (Chiov.) Sacl.	*Anacardiaceae*	Waan adii	T
Lannea schimperi (A.Rich.) Engl.	*Anacardiaceae*	-	T

Continued to Appendix 1.

Scientific name	Family	Local name*	Habit**
Lannea triphylla (A. Rich.) Engl.	*Anacardiaceae*	Handarakkuu	T
Ozoroa insignis Del. subsp. *insignis*	*Anacardiaceae*	Garrii	T
Rhus natalensis Krauss (Wight &Arn.)Walp.	*Anacardiaceae*	Laboobessa	S
Rhus ruspolii Engl.	*Anacardiaceae*	Hirqee	S
Rhus vulgaris Meikle	*Anacardiaceae*	Laboobessa	S
Chlorophytum gallabatense Schweinf. ex Baker	*Anthericaceae*	Burii xiqqaa	H
Steganotaenia araliacea Hochst. ex A. Rich.	*Apiaceae*	-	S
Carissa spinarum L.	*Apocynaceae*	Hagamssa	S
Saba comorensis (Boj.) Pichon	*Apocynaceae*	-	C
Secamone punctulata Decne.	*Asclepiadaceae*	Gaalee	C
Gomphocarpus fruticosus (L.) Ait. f. subsp. *flavidus* (N.E.Br.) Goyder	*Asclepiadaceae*	Gurbii aannoo	H
Sarcostemma viminale (L.) R. Br.	*Asclepiadaceae*	-	C
Secamone parvifolia (Oliv.) Bullock	*Asclepiadaceae*	Gaalee kiikkii	C
Asparagus aridicola Sebsebe	*Asparagaceae*	Sariitii	S
Asparagus flagellaris (Kunth) Baker.	*Asparagaceae*	Hoolota	S
Asparagus scaberulus A. Rich.	*Asparagaceae*	Sariitii	S
Acanthospermum hispidum DC.	*Asteraceae*	Qoree tigree	H
Bidens pilosa L.	*Asteraceae*	Cogee	H
Gutenbergia somalensis (O.Hoffm.) M.G. Gilbert	*Asteraceae*	-	H
Guttenbergia rueppellii Sch. Bip. Var. *rueppellii*	*Asteraceae*	-	H
Kleinia abyssinica (A. Rich) A. Berger var. *abyssinica*	*Asteraceae*	Habraasa	H
Kleinia abyssinica (A. Rich) A. Berger var. *hildebrandtii* (Vatke) C.Jeffrey	*Asteraceae*	Habraasa	H
Tagetes minuta L.	*Asteraceae*	-	H
Zinnia peruviana (L.) L.	*Asteraceae*	-	H
Balanites aegyptiaca (L.) Del.	*Balanitaceae*	Baddannoo	T
Stereospermum kunthianum Cham.	*Bignoniaceae*	Botoroo	T
Cordia africana Lam.	*Boraginaceae*	Waddeessa	T
Cordia monoica Roxb.	*Boraginaceae*	Leedy	T
Boswelia neglecta S. Moore	*Burseraceae*	Qumbii	T
Commiphora africana (A. Rich.) Engl. var. *africana*	*Burseraceae*	Iddaa	T
Commiphora baluensis Engl.	*Burseraceae*	Hagarsuu	T
Scientific name	Family	Local name*	Habit
Commiphora habessinica (Berg) Engl.	*Burseraceae*	Xiillaa	T
Commiphora myrrha (Nees) Engl.	*Burseraceae*	Liboo	S
Commiphora serrulata Engl.	*Burseraceae*	-	T
Boscia angustifolia A. Rich. var. *angustifolia*	*Capparidaceae*	Qanqalcha	S
Boscia senegalensis Lam. ex Poir.	*Capparidaceae*	-	T
Capparis fascicularis DC.var. *fascicularis*	*Capparidaceae*	-	S
Maerua triphylla A. Rich. var. *Pubescens* (Klotzsch) DeWolf	*Capparidaceae*	-	S
Maytenus gracilipes (Welw.ex Olive.) Exell subsp. *arguta* (Loes.)	*Celastraceae*	Combolcha	S
Maytenus senegalensis (Lam.) Exell	*Celastraceae*	Laboobessa	S
Combretum aculeatum Vent.	*Combretaceae*	Hurufoo	S
Combretum adenogonium Steud.ex.A.Rich	*Combretaceae*	Dareessa	T
Combretum collinum subsp. Binderianum (Kotschy) Okafor	*Combretaceae*	Dhandhanssa	T
Combretum molle R. Br. ex G. Don	*Combretaceae*	Birdhee lukoo	T
Terminalia brownii Fresen.	*Combretaceae*	Birdheessa	T
Terminalia polycarpa Engl. & Diels	*Combretaceae*	Hererrii	T
Aneilema somaliense C.B. Clarke	*Commelinaceae*	Korma iluu	H
Commelina africana L.	*Commelinaceae*	-	H
Murdannia simplex (Vahl) Brenan	*Commelinaceae*	Qayyoo	H
Ipomoea donaldsonii Rendle	*Convolvulaceae*	Xuuxxoo	S
Ipomoea indica (Burm.f.) Merrill var. *acuminata*	*Convolvulaceae*	Dabaagisa	H
Ipomoea triflora Forssk.	*Convolvulaceae*	-	H
Kalanchoe lanceolata (Forssk.) Pers.	*Crassulaceae*	Boobiyyaa	H

Continued to Appendix 1.

Scientific name	Family	Local name*	Habit**
Coccinia abyssinica (Lam.) Cogn.	*Cucurbitaceae*	Saarii jeedalaa	H
Cucumis ficifolius A.Rich	*Cucurbitaceae*	Qummuuxxoo	H
Mimordica trifoliolata Hook. f	*Cucurbitaceae*	-	H
Asepalum eriantherum (Vatke) Marais	*Cyclocheilaceae*	Firaan qaandolee	S
Diospyros abyssinica (Hiern) F.White	*Ebenaceae*	Lookoo	T
Diospyros mespiliformis Hochst. ex A. DC.	*Ebenaceae*	-	T
Euclea racemosa Murr.subsp. *schimperi* (A. DC.) White	*Ebenaceae*	Mi'essa	S
Acalypha volkensii Pax	*Euphorbiaceae*	-	H
Croton dichogamus Pax	*Euphorbiaceae*	Maakaftaa	S
Croton macrostachyus Del.	*Euphorbiaceae*	Bakkaniissa	T
Euphorbia tirucalli L.	*Euphorbiaceae*	Aannoo	S
Tragia mixta M.Gilbert	*Euphorbiaceae*	Laalessaa	S
Faidherbia albida (Del.)A. Chev.	*Fabaceae*	-	T
Acacia brevispica Harms.	*Fabaceae*	Hamareessa	S
Acacia bussei Harms ex sjÖstedt	*Fabaceae*	Haalloo	T
Acacia etbaica Schweinf. subsp. *platycarpa* Brenan	*Fabaceae*	Burquqqee	T
Acacia mellifera (Vahl) Benth	*Fabaceae*	Bilaala	T
Acacia nilotica (L.) Willd. ex. Del. subsp. *Kraussiana* (Benth.) Brenan	*Fabaceae*	Doddotii	T
Acacia robusta Burch. subsp. *usambarensis* (Taub.) Brenan	*Fabaceae*	Waangayya	T
Acacia senegal (L.) Willd. var. *senegal*	*Fabaceae*	Saphanssa	T
Acacia seyal Del	*Fabaceae*	Waachuu	T
Acacia tortlis (Forssk.) Hayne. subsp. *spirocarpa* (Hochst. ex A. Rich.) Brenan	*Fabaceae*	Xaddacha	T
Crotalaria emarginella Vatke	*Fabaceae*	-	H
Dalbergia microphylla Chiov.	*Fabaceae*	Chalchala	T
Delonix elata (L.) Gamble	*Fabaceae*	Shukkeellaa	T
Dichrostachys cinerea (L.) Wight and Arn.	*Fabaceae*	Jirmee	T
Entada leptostachya Harms	*Fabaceae*	Dhangaa gaalaa	C
Scientific name	Family	Local name*	Habit
Indigofera brevicalyx Bak.f	*Fabaceae*	Tiiraa	H
Indigofera insularis Chiov.	*Fabaceae*	-	H
Indigofera spicata Forssk.	*Fabaceae*	-	H
Indigofera volkensii Taub.	*Fabaceae*	-	H
Ormocarpum trichocarpum (Taub.) Engl.	*Fabaceae*	Buutee	S
Piliostigma thonningii (Schumach.) Milne-Redh.	*Fabaceae*	-	T
Senna baccarinii (Chiov.)Lock	*Fabaceae*	Gurbii dhigrii	H
Senna obtusifolia (L.)	*Fabaceae*	-	T
Stylosanthes fruticosa (Retz.) Alston	*Fabaceae*	-	H
Tamarindus indica L.	*Fabaceae*	Roqaa	T
Zornia apiculata Milne-Redh.	*Fabaceae*	Saarii	H
Flacourtia indica (Burm. f.) Merr.	*Flacourtiaceae*	Akuukkuu	T
Pyrenacantha malvifolia Engl.	*Icacinaceae*	Burii guddaa	C
Becium filamentosum (Forssk.) Chiov.	*Lamiaceae*	Tiiraa	H
Erythrochlamys spectabilis Gürke	*Lamiaceae*	-	S
Leucas martinicensis (Jacq.) R.Br.	*Lamiaceae*	-	H
Ocimum froskolei Benth	*Lamiaceae*	Urgoo loonii	S
Ocimum urticifolium Roth	*Lamiaceae*	Urgoo harree	S
Orthosiphon macrocheilus M. Ashby	*Lamiaceae*	-	H
Orthosiphon thymiflorus (Roth) Sleesen	*Lamiaceae*	-	H
Premna oligotricha Baker	*Lamiaceae*	Adaaddii	S
Strochynos mitis S. Moore	*Loganiaceae*	Sidaamoo	T
Sida ovata Forssk.	*Malavaceae*	Qarxaaxummii	S
Sida urens L.	*Malavaceae*	-	H
Abutilon figarianum Webb	*Malvaceae*	Bulaan bulcha	H
Hibiscus calyphyllus Cavan.	*Malvaceae*	-	S

Continued to Appendix 1.

Scientific name	Family	Local name*	Habit**
Hibiscus micranthus L.f.	*Malvaceae*	Gurbii gurraatii	H
Pavonia procumbens (Wight & Arn.) Walp.	*Malvaceae*	Gurbii	H
Cissampelos pareira L. var. *hirsuta* (Buch.ex DC.) Forman	*Menispermaceae*	Gaalee	H
Ficus cycomorus L.	*Moraceae*	Odaa	T
Syzygium guineense (Willd.) DC. subsp. *guineense*	*Myrtaceae*	Baddeessaa	T
Commicarpus plumbagineus (Cav.) Standl	*Nyctaginaceae*	-	H
Ochna inermis (Forssk.) schweinf ex Penzig	*Ochnaceae*	Elelenqaa	S
Ximenia americana L.	*Olacaceae*	Hudhaa	S
Jasminum abyssinicum Hochst ex DC.	*Oleaceae*	-	H
Jasminum grandiflorum L. subsp. *Floribundum* (R.Br.ex Fresen	*Oleaceae*	Qarxaaxummii gurraatii	H
Olea europaea L. subsp.*cuspidata* (Wall. ex G. Don) Cif.	*Oleaceae*	Ejerssa	T
Sesamothamnus rivae Engl.	*Pedaliaceae*	Dareessa	T
Chloris roxburghiana Schult.	*Poaceae*	-	H
Dignathia hirtella Stapf	*Poaceae*	Marga gurra babal'aa	H
Ehrharta erecta Lam. v*ar. abyssinica* (Hochst.) Pilg.	*Poaceae*	-	H
Perotis patens Gand.	*Poaceae*	Marga	H
Tetrapogon tenellus (Roxb.) Chiov.	*Poaceae*	-	H
Berchemia discolor (Klotzch) Hemsl.	*Rhamnaceae*	Jajjaba	T
Ziziphus abyssinica Hochst.ex A. Rich.	*Rhamnaceae*	Qurquraa	T
Ziziphus mauritiana Lam.	*Rhamnaceae*	Qurquraa	T
Ziziphus spina-christi (L.) Desf.	*Rhamnaceae*	Qurquraa	T
Breonadia salicina (Vahl) Hepper& Wood	Rubiaceae	-	T
Canthium pseudosetiflorum Bridson	*Rubiaceae*	Ladhana	S
Gardenia ternifolia Schumach. & Thonn.	*Rubiaceae*	Gambeelloo	T
Psydrax schimperiana (A.Rich) Bridson subsp. *schimperiana*	*Rubiaceae*	-	S
Scientific name	Family	Local name*	Habit
Teclea nobilis Del.	*Rutaceae*	Hadheessa	T
Zanthoxylum chalybeum Engl.	*Rutaceae*	Gaddaa	T
Dobera glabra (Forssk.) Poir.	*Salvadoraceae*	Aadee	T
Allophylus macrobotrys Gild	*Sapindaceae*	-	S
Allophylus rubifolius (Hochst. ex A. Rich). Engl.	*Sapindaceae*	-	S
Dodonaea angustifolia L. f.	*Sapindaceae*	Ittacha	S
Haplocoelum foliolosum (Hiern) Bullock	*Sapindaceae*	Canaa	T
Pappea capensis Eckl. & Zeyh.	*Sapindaceae*	Biiqqaa	T
Harrisonia abyssinica Oliv.	*Simaruabaceae*	Goraa	S
Kirkia burgeri Stannard subsp. *burgeri*	*Simaruabaceae*	Musdhugaa	T
Physalis lagascae Roem & Schult.	*Solanaceae*	-	H
Solanum incanum L.	*Solanaceae*	Hiddii	S
Withania somnifera (L.)	*Solanaceae*	-	S
Melhania ovata (Cav.) Spreng.	*Stericulaceae*	-	H
Gnidia stenophylla Gild	*Thymelaeaceae*	Qaxaricha	H
Grewia bicolor Juss	*Tiliaceae*	Harooressa	S
Grewia ferruginea Hochst.ex A. Rich	*Tiliaceae*	Xaaxessaa	S
Grewia mollis Juss.	*Tiliaceae*	Ulee qaalluu	S
Grewia velutina (Forssk.) Vahl	*Tiliaceae*	Harooressa gurraacha	S
Grewia villosa Willd.	*Tiliaceae*	Ogomdii	S
Triumfetta flavescens Hochst.	*Tiliaceae*	-	H
Triumfetta pentandra A.Rich.	*Tiliaceae*	Gurbii	H
Clerodendrum myricoides (Hochst.) R. Br. ex Vatke	*Verbenaceae*	Urgoo ajaawwaa	S
Cissus aphylla Chiov.	*Vitaceae*	-	C
Cissus quadrangularis L.	*Vitaceae*	Cobii	C
Cyphostemma niveum (Hochst.ex Schweinf.) Descoings	*Vitaceae*	Liqimmee	H
Rhoicissus tridentata (L.f.) Wild & Drummond	Vitaceae	Laluu	C

**Afan Oromo; ** H= herbs; S= shrubs; F= ferns; T= trees; C= climbers*